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Conditions and possibilities of direct utilisation of thermal-mineral waters in Raska region, Serbia

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ABSTRACT

The natural thermal-mineral springs in the Raska region in Serbia have been known since the ancient period. Temperatures of these sources between 26 °C and 51 °C have allowed the use of water for balneology and recreational purposes. Research over the past 50 years have pointed to the existence of significant amounts of thermal-mineral waters that occur in different tectonic zones and faults in the Dinarides. Bearing in mind the properties of thermal-mineral waters the paper deals with possibilities of their use as a renewable resource. The paper analyses the way of use of waters in three spas and one spring for health and recreational purposes and presents the possibilities for improving the use of unused water. The results hint at the possibility of direct use of heat energy from TM sources and substitution of fossil fuels, expenses of living and work in local communities. Direct use of geothermal energy, especially during the colder period of the year, would reduce the expenses of heating of public institutions, services and private households.

Contents

1. Introduction

The use of thermal-mineral (TM) springs is one of the oldest forms of recognition and use of natural resources. In Serbia, which is a relatively small area (88,407 km^2), a number of TM springs occurs. They are the result of geological complexity marked by rocks of different times and ways of the foundation, mineralogical and petrologic characteristics. On this basis, a geological regionalisation of Serbia was made on six large tectonic regions (Fig. 1) [1].

The estimated capacities of geothermal energy used in Serbia are 100.8 MWt, and therefore it is among the top 36 countries [2]. On a global geothermal map Serbia is marked as a country in which the TM waters are used mainly for balneology purposes, recreation and bottling. Small share of geothermal energy is used for other purposes [2,3].

Exploitation of TM waters in Serbia has much longer history than scientific research. Hot springs–baths, for bathing and rehabilitation, were used in the classical period. The material remains and preserved cultural heritage of the Middle Age, presented by many Serbian monasteries and ancient cities, are located near the TM sources. Also, during the Ottoman rule from the 15th to the 19th century, the TM springs baths were built, known as Turkish baths [4]. Modern studies of TM sources from a geological aspect are the result of interest to make an inventory of available resources, to increase the discharge, to eliminate the negative environmental consequences [5]. Scientific papers from the first decade of the 21st century have dealt with the TM sources in Serbia from the aspect of their use as renewable energy, and the

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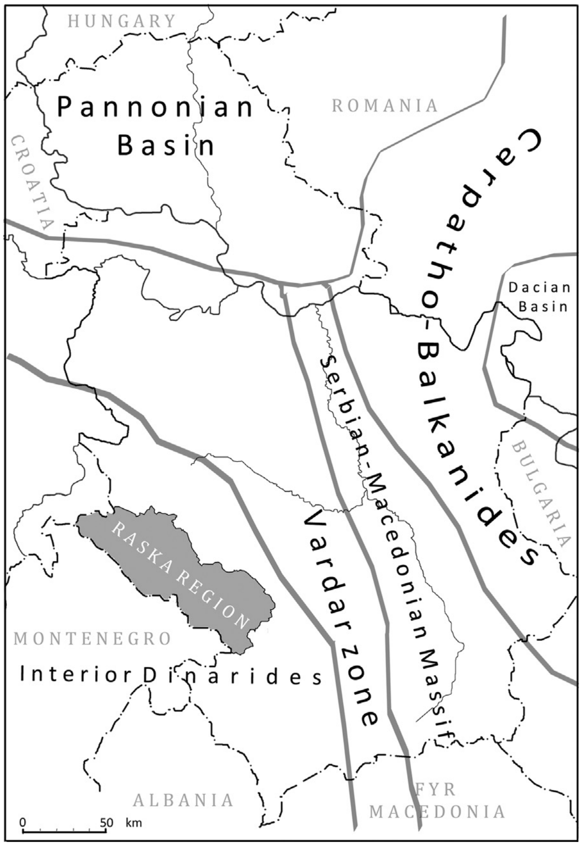


Fig. 1. Position of the RR in relation to the basic geotectonic units in Serbia.

possibilities of substitution of fossil fuels [6–11], the radioactivity of water [12,13], and the exploitation in spa tourism [14–17]. Geothermal energy is a very little exploited renewable resource of Serbia as only 5.2% of total potentials are used [18].

Raska region (RR) is a border region, geographic region in south-western Serbia and north-eastern Montenegro. In Serbia, it includes the area of 4509 km^2, with 229,382 inhabitants in 441 settlements (2011 Census). In tectonic terms, it is in the area of Internal Dinarides and based on the Vardar zone toward the east (Fig. 1) [1,19]. The oldest traces of the use of TM springs in the RR date from the classical period. Their health importance is known to the local population. Recent studies of TM waters are conducted, from the mid-20th century in locations with the most significant TM sources in the following regions: (1) Novopazarska Spa, (2) Rajcinovica Spa, (3) Pribojska Spa, (4) Cedovo village, (5) village of Slatina, (6) Dezevo village, and (7) Black spring in Nova Varos.

The study of geothermal energy in the RR in the past was directly related to the possibilities of their use for heating and balneology. TM springs in the RR have not attracted the attention of researchers due to peripheral location in relation to the main geothermal energy flows in Serbia, that is, the priority areas of research [20]. Therefore, studying the properties of water was done specifically for the needs of scientific papers, medical institutions and studies.

The aim of this paper is to consider the possibilities of using TM waters in the RR. Regarding the evaluation of the supportability of exploitation, the authors have been guided by the fact that the geothermal energy is a limited occurrence and a resource which is tied to the geographic location [21]. Also, the researched sources are located in a seismically comparatively stable region. The main tasks are (1) analysis of the impact of geological conditions on the occurrence of TM waters, (2) classification and systematisation of sources on the basis of physical, chemical and therapeutic characteristics, and (3) establishment of existing and future ways of direct use of thermo-mineral waters as a heat energy, especially from the point of view of spa tourism.

2. Methods and data

The spatial framework of the research is a geographical and historical region of Raska, part of the border, mountainous area of southwest Serbia. Administratively, it includes six municipalities of which five have the status of underdeveloped ones according to the criteria of Regional Development of Serbia 2007–2012 [22]. We studied four sites with the phenomena of TM waters in Novopazarska Spa, Pribojska Spa, Rajcinovici and Cedovo. TM waters occur in the form of springs and wells in the municipalities Novi Pazar (Novopazarska Spa and Rajcinovica Spa), Priboj (Pribojska Spa) and Sjenica (Cedovo). Around TM sources there are suburbs of the same name. The analysed samples of TM waters originate from the period 1989 to 2008 and come from documentary material of hydro, laboratory, and balneology institutions (Rehabilitation Institute – balneology–climatology service, Faculty of Mining and Geology, University of Belgrade).

In addition to theoretical research of literature we used the methodology of modern hydro-geology to calculate thermal capacity, energy use and conversion of the obtained results in the energy of fossil fuels. Indicators of geothermal energy (heat power/thermal capacity) of TM waters were made on the basis of the following formula [8]:

$$\text{CAP (MWt)} = \text{FR}_{\text{max}}\ (\text{kg/s}) \times [\text{inlet temp. } (^{\circ}\text{C})\text{–outlet temp. } (^{\circ}\text{C})] \times 0.004184\ (\text{MW}), \quad (1)$$

where CAP stands for Thermal Capacity and FR stands for Flow Rate.

The total energy of the waters is derived by the following formula [8]:

$$E\ (\text{TJ/year}) = \text{FR}_{\text{avg}}\ (\text{kg/s}) \times [\text{inlet temp. } (^{\circ}\text{C})\text{–outlet temp. } (^{\circ}\text{C})] \times 319\ (\text{TJ}) \quad (2)$$

where E stands for Energy use.

Equivalence of energy, i.e. calorific value, is performed according to current definitions of the International Agency for Energy (IAE) and standard conversion factors (UNSTAT): joule (J) – international (S.I.) unit of energy; kilowatt hour (kWh) – conventional unit of energy that electricity is measured and charged for commercially; and tonne of Oil Equivalent (toe) – conventional standardized unit of energy and is defined on the basis of a tonne of oil having a net calorific value of 41,686 kJ/kg [23,24]. The statistical method, comparison and systematisation have been used in data processing. Some results are shown by the mapping method. The research results have served the authors to identify how TM springs and spas can contribute to the development of tourism and other economic branches in the RR on the principles of sustainable development.

3. Regional review and geological settings

RR is the part of mountainous macro-region of Serbia. The relief includes mountains of medium height – up to 1850 m (Zlatar, Golija Jadovnik Giljeva, and Pobijenik), high plateaux and valleys (Pesterska, Sjenicka, and Novopazarska), karst fields (Kostam Polje) and the canyon and gorge valleys (Lim, Uvac, Raska, and Ibar) [25].

The studied region is heterogeneous by geological composition. In this area many types of sediments, igneous and metamorphic rocks are developed. According to Petkovic [26], RR is very poor in permeable areas, and occurrence of alluvium is rare. Karst groundwater is of limited space. It can be conditionally divided into two

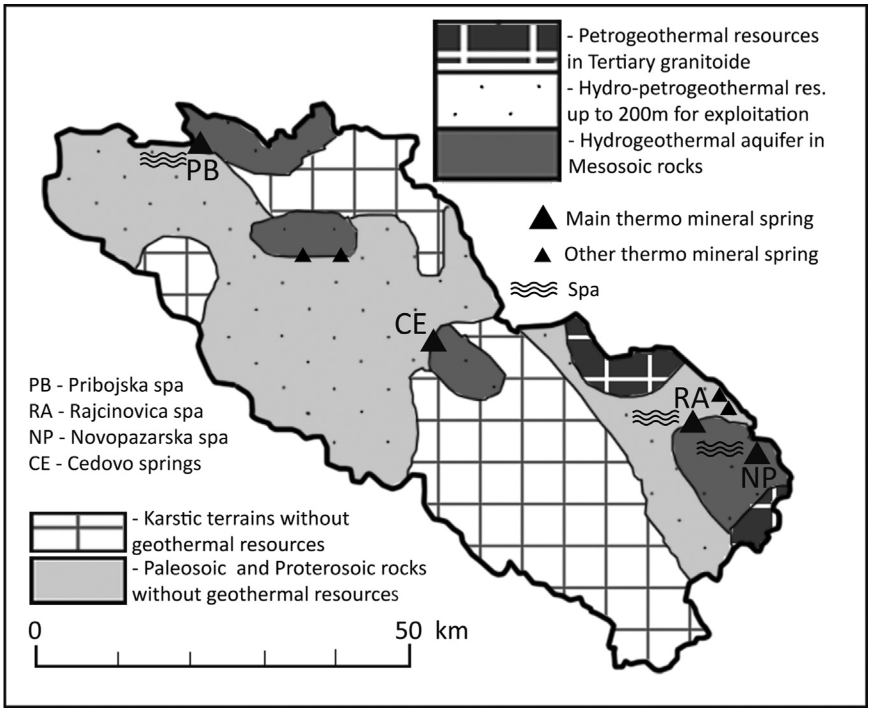


Fig. 2. Geological formations and TM springs in Raska region.

sub-regions: (1) greater north-western zone, dominated by ophiolites and Mesozoic limestone and (2) smaller south-eastern zone, built of Palaeozoic schist, flysch and volcanic rocks of Tertiary age [1].

In considering the hydro-geological conditions, we shall review only the major sedimentary formations that are the carriers of significant accumulations of ground waters: the Triassic limestone, diabase–chert formation of wider ophiolitic belt and Neogene formations. The density and importance of the appearance of TM waters in RR are lower than in neighbouring areas in Serbia. We will present a brief regional overview of the studied TM sources:

(a) TM springs of Pribojska Spa occur in the valley of the River Lim, in the border belt of Serbia towards Bosnia and Herzegovina and the RR in the west (Fig. 2). They are linked to the west slopes of Banjsko brdo (1282 m), where water runs off at the contact of limestone with diabase–chert formation.
(b) Novopazarska Spa and Rajcinovica Spa are located in the Raska river basin, in the southeast of the studied region (Fig. 2). TM sources are 50–60 km thick in the layer of the lithosphere, characterised by intensive geothermal and tectonic activity. Geothermal characteristics are associated with volcanic rocks, plutonic masses of Rogozna Mountain [27]. TM waters occur at several places along the fault. The tectonic activity causes the occurrence of hyper-thermal waters.
(c) Cedovo TM springs are located on the edge of the Sjenica Tertiary basin, in the Vapa river valley. There are about 20 springs registered in the area of 500 m the underground collectors of which are the Triassic limestone. North of the springs the terrain consists of rocks of Jurassic diabase–chert formation and the Triassic limestone, while in the south there are Neogene sandy–clayey sediments and alluvium of the river Vapa [1].

4. Thermal-mineral waters in the spa areas of Raska region

Scientific researches of TM waters of Novopazarska Spa were conducted in the period 1954–1990 in several stages. Several boreholes were made and the physical and chemical properties of water examined in detail. Rajcinovica Spa was first scientifically researched in 1954 when the first boreholes were made. Test results indicated the basic properties of TM waters from three springs. The first analyses of water of Pribojska Spa were made in 1878 in laboratories in Vienna. They were used to determine the medicinal properties and other characteristics. In historical records, during the medieval Serbian state in the 12th century it was mentioned under the name of Kaldane. In the Ottoman period it was known as the Spa Petka, and after the liberation from the Turkish rule, it was named Ilidze Spa [28]. Modern use of water takes place since the founding of the Rehabilitation Centre ‘Spa’ in 1971. The study found that water is effective in treating rheumatic, post-traumatic, neurological, gynaecological, dermatological, digestive disorders and sports injuries. TM springs near the village Cedovo are explored later. According to Krstic [29], there are two significant springs ‘Banjica’ and ‘Banja’. Since the initial research, capture or arrangement of springs has not been done and the water flows freely into the river Vapa.

TM springs in the RR are located at altitudes from 502 m to 981 m. They vary according to temperature, discharge, chemical and gas composition and geothermal energy. For the four springs studied, water temperatures ranged from 26.3 to 51 °C (Table 1). The total discharge of TM springs is about 105 l/s. Pribojska Spa has the highest discharge where springs are at the contact of limestone and diabase–chert formation. Based on the maximum and minimum temperatures, the estimated total geothermal energy is 195.06 TJ/year, and thermal capacity is 6.17 MWt. The values of heat flow in the lithosphere range from 65 mW/m^2 in Pribojska Spa to 100 mW/m^2 in the area of Novopazarska Spa (Fig. 3). High temperatures in the layers decrease in the direction northeast–southwest. Main features of TM springs are given in Tables 1 and 2. We will analyse the TM waters according to the phenomena of water in the spa regions.

(1) The first analyses of water of Pribojska Spa were made in 1878 in laboratories in Vienna. They were used to determine the medicinal properties and other characteristics. The most famous springs in Pribojska Spa are ‘Stara Banja’ and ‘Nova

Table 1
Review of basic indicators of some springs and wells in Raska region.
Source: Official laboratory of Department of Hydrogeology, Faculty of Mining and Geology, Belgrade.

Spa name	Discharge (l/s)	Water temperature (°C)	Total mineralisation (g/l)	Capacity (MWt)	Energy use (TJ/year)
Novopazarska Spa	5	51	1.58	0.65	20.49
Rajcinovice Spa	8	40	2.82	0.26	8.44
Pribojska Spa	70	36	0.49	4.69	147.85
Cedovo	22	26.3	0.31	0.57	18.28
Total	105			6.17	195.06

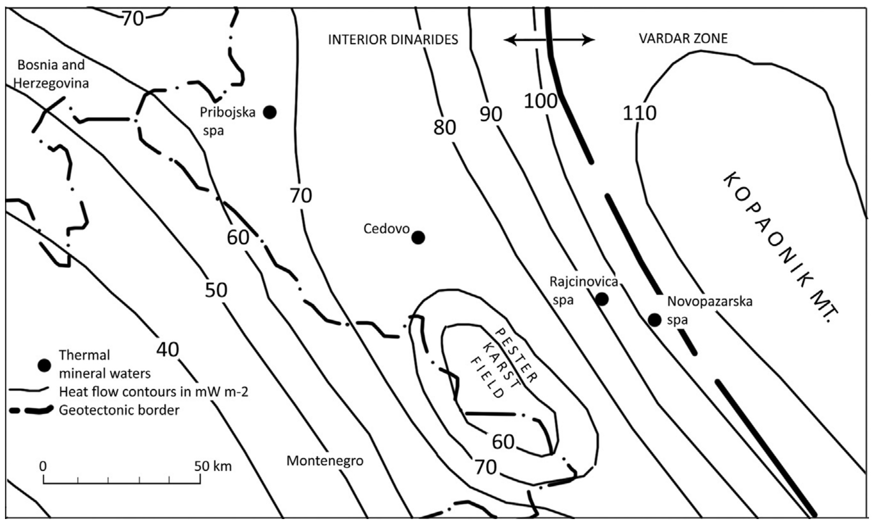


Fig. 3. Heat flow map in Raska region (based on [8]).

Table 2
Waters of Raska region by chemical type and content of therapeutic active components.
Source: Official laboratory of Department of Hydrogeology, Faculty of Mining and Geology, Belgrade.

Spa name Chemical type		Novopazarska Spa HCO_3–Na	Rajcinovice Spa HCO_3–Na–Cl	Pribojska Spa HCO_3–Ca–Mg	Cedovo HCO_3–Ca
mg/l	J	–	<0.5	–	0.01
	Br	<0.05	<0.05	<0.25	0.05
	Fe	0.02	0.02	<0.01	0.15
	Li	0.4	1.15	<0.05	0.002
	Sr	1	1.95	<0.05	0.1
	B	10.7	–	<0.05	0.2
	Zn	0.002	–	<0.005	<0.005
	Mn	0.03	0.03	<0.01	0.001
	Cl	3	131.4	3	5
	Al	<0.05	0.06	<0.05	0.03
	SiO_2	–	31.8	19	10
	$HC0_3$	1070	1830	275	220
	HBO_2	1.1	–	–	0.2
	H_2SiO_3	6.2	–	–	–
Bq/l	Ra	–	–	0.27	0.59
	Rn	–	–	–	12.6

Banja'. Water temperature in the first spring is 37.5 °C and the other 35.7 °C, making them homoeothermic spas. Spring 'Stara Banja' belongs to the category of oligomineral (0.41 g/l), sulphur and slightly alkaline waters with no colour, taste and smell. Spring 'Nova Banja' is of HCO_3–Ca–Mg character, with low mineralisation (0.49 g/l) [30]. Total discharge of the spring is 70 l/s, and geothermal capacity is estimated at 4.69 MWt allowing 147.85 TJ/year. Therefore, Pribojska Spa has the largest geothermal potential of all geothermal spas in RR.

(2) Most significant physical feature of Novopazarska Spa is the temperature of TM waters. It ranges from 52 to 54.6 °C, and therefore belongs to the hyper-thermal spas. For the purposes of the Old Bath and of the Hospital six springs were captured of water inflow from 0.8 l/s to 2.4 l/s. Capped water temperature is 51 °C [27].
Water of Novopazarska Spa is known for its health resort properties. According to the mineral composition water is slightly acid, hydro-carbonate–sodium (HCO_3–Na), mineralisation of 1.58 g/l

and pH 6.8. Presence of nitrogen is most (70%), and the content of dissolved CO_2 is 176 mg/l [31]. Based on them, a tradition of spa treatment and rehabilitation is created. The chemical composition is distinguished by HCO_3 (1070 mg/l) as macro-component. Among therapeutically active components there are Li (0.4 mg/l), Sr (1 mg/l), B (10.7 mg/l) and H_2S (1 mg/l). Based on the discharge of 5 l/s, and internal and external temperatures of water, the estimated capacity of Novopazarska Spa is 0.64 MWt with thermal energy of 20.49 TJ/year.

Rajcinovica Spa was first scientifically researched in 1954 when the first boreholes were made. Test results indicated the basic properties of TM waters from three springs. According to the temperature of water at the surface of 30–32 °C it belongs to hypothermal spas; however, the measured temperature at larger depth reaches 42 °C and is therefore hyper-thermal. In addition to warm, the two cold springs are captured which lie closer to the surface and the discharge of which depends on atmospheric conditions. The temperature of cold springs is from 5.5 to 10 °C. According to the chemical composition they belong to alkali–acid waters – HCO_3–Na–Cl. Among therapeutically active components, we highlight J (0.5 mg/l), Li (1.15 mg/l), Sr (1.95 mg/l) and SiO_2 (31.8 mg/l). According to these parameters, Rajcinovica Spa is the most medicinal one in the RR. The total discharge of the spring is 8 l/s, and geothermal energy capacity is 0.268 MWt, with used energy of 8.44 TJ/year [7].

(3) Cedovo TM waters are the least explored. In the area of 500 m, there are 20 registered springs. The most significant springs are 'Banja' and 'Banjica'. The second is a karst spring, circular in shape, 10 m long, 8 m wide and a depth of 0.7 m. The total discharge of all springs is estimated at 22 l/s. Water is representative of the karst thermal waters and according to the type is HCO_3–Ca. Total mineralisation is 0.31 g/l and pH – 7.5. In the gas composition of water nitrogen prevails (over 83% by volume). Ra content is high – 0.59 Bq/l, while the content of other radioactive elements is low.

5. State and possibilities of the use of thermal-mineral waters

TM springs in the RR are few in number compared to other regions of Serbia. They are currently used solely for balneology and recreational purposes in the treatment, rehabilitation and recovery of the population and tourists. On the other hand, according to exposed physical, chemical and geothermal properties, they could be used in agriculture for heating greenhouses, drying fruits and vegetables, food processing, on livestock farms, for the supply of the sanitary hot water, in the fishing industry, for bottling, etc. [32].

According to Jovicic [17], the most important tourist Serbian spas have developed around TM springs in the basins of the rivers Zapadna Morava and Juzna Morava. The Zapadna Morava river basin includes Novopazarska Spa and Rajcinovica Spa. The division on nine spa zones by Markovic [33] corresponds more to the regional-geographic approach of the research of spas according to which Novopazarska, Rajcinovica and Pribojska Spas belong to the common Novi Pazar–Priboj zone. These are typical European spas located next to the springs of TM waters in the suburban area. The rehabilitation centres are built in spas i.e. specialized hospitals with ancillary facilities that directly use TM water. However, tourism function of spas is secondary due to rooted traditional medicinal concept of spas in Serbia.

In the period 1948–1960, according to the needs of the state, the spas had mostly medical role. In the early seventies of the 20th century, hotels, restaurants and new rehabilitation centres were built in spas [34]. Population goes to spas not only for health but a need for recreation and rest. Spas near large towns and municipal centres have become the agents of tourism development and tourist flows are directed to them. As an important factor in spa tourism offer also influenced the fact that Serbia is a landlocked country, which redirected tourist movements, especially in the last 20 years. Tourism in continental conditions, contributed to the development of spas with outstanding geographical position, transport availability and tradition. In Novopazarska, Pribojska and Rajcinovica Spas, the development is difficult due to the unfavourable traffic and geographical position (peripheral and marginal position in the country; and distance from main roads and poor regional road network) and the considerable distance from major tourist generating centres. Over the past 20 years, Serbia has been poorly represented in the international tourism market and supply factors are focused on the domestic market. According to Bjeljac [35], this has led to a massive, i.e. social, labour, youth and children tourism as a major form of tourism in spas. In addition to the existing tourist offer of spas of RR characterised by medical-health and recreational functions, in the period 2000–2010 ethno-tourism, eco-tourism and religious tourism developed. We will consider the use of TM waters from the point of the health-medicinal tourism.

Health waters in the European literature are classified into several groups according to the significance and representation of therapeutically active components (CO_2, HCO_3, Ca–Mg, Na–Cl, Fe, HS, S, H_2S, SO_4, Br, and Ra) and temperature (higher than 25 °C) [36,37]. Thus, the abundance of different mineral components and gases, and not only salt, provides water healing properties [38]. Waters in four studied spas differ by healing properties. In the waters of Novopazarska Spa and Rajcinovica Spa the mineral healing micro-components and HCO_3 are more represented, while the waters of Pribojska Spa and Cedovo are slightly radioactive (Table 2).

(1) Based on available data, it can be said that the waters of Pribojska Spa were known a thousand years ago. Spa waters have been used in the Roman, medieval, Turkish and modern times. It is believed that the Spa experienced the greatest splendour during Nemanjic, when St. Sava here formed the Dabar bishopric with the main office in Banja monastery [39]. The proof of that is material evidence and the sacred heritage of the Spa environment, but there is no concrete evidence of the use of water. Modern use of water takes place since the founding of the Rehabilitation Centre 'Banja' in 1971. Thermal water fills four indoor pools. The study found that water is effective in treating rheumatic, post-traumatic, neurological, gynaecological, dermatological, digestive disorders and sports injuries.

(2) According to archaeological evidence, it is assumed that the springs of Novopazarska Spa were used in Bronze Age (1200 years BC) [40]. The Romans built two bathrooms in this area. Continuity of water use is in sight during the Middle Ages, when there were a natural spa and bathrooms of Raska there and two Turkish baths (16th century) and caravanserai for the accommodation. Old bathroom is now the oldest building in the spa and it was the work of Caliph Ahmed Pasha from 1593. It is of oriental type, reconstructed in the 19th century. Functionally and aesthetically it reflects authenticity and tradition of the spa. In modern conditions, waters are used for medical purposes in the Special Hospital for Treatment of Progressive Muscle and Neurological Diseases, which was opened in 1957. TM water properties are favourable for treatment of diseases of the loco-motor apparatus, rheumatic, neurological, gynaecological and dermatological diseases [16]. Based on field research, we found that the waters of Rajcinovica Spa were used in the Middle Age. Today they are mostly used by local people for bathing and drinking, throughout balneology-healing treatments. Within the Raj Hotel, there is a

pool that is used for bathing and as a therapy for the treatment of rheumatic and neurological diseases. It is believed that cold water has positive effects on diseases of abdomen.

(3) TM waters in Cedovo are used by local people for bathing in the completely disordered conditions. Springs are not capped and the water flows freely. In an interview with local residents who use water for bathing, we learned that it has a beneficial effect in rheumatic diseases.

Travel feature of spas is inseparable from the natural and cultural motifs in the RR. The authenticities of the offer are protected natural and sacred sites from the list of UNESCO World Cultural Heritage: Nature Park – Golija Mt., Stari Ras and Sopocani monastery, Studenica monastery and the monastery of Djurdjevi Stupovi. Tourists also found interesting the mixed Islamic and Christian cultural heritage presented by religious sites and environmental quarters in cities. In the last 20 years there have been changes in the number, type and quality of accommodation in the spas of RR. In the period 1991–2010, some facilities have gone through the process of privatisation and renovations, but new ones are also built. Hotels are deployed in the city centre and along main roads. Spa tourism is linked to the city centres of Novi Pazar and Priboj. Number of beds in Novi Pazar increased from 580 to 820, while in Priboj decreased from 861 to 282. In the area of the municipalities of Novi Pazar and Priboj there are 20 accommodation facilities with 1090 beds.

In Novi Pazar there are eight hotels of which two are rehabilitation centres. Total capacity is 820 beds. In Priboj accommodation structure is different. There are two hotels with 244 beds. Total offer of 282 beds is completed by rooms, guesthouses and apartments in private accommodation. It is considered that there is much more beds in unregistered private accommodation. Total accommodation capacity in spas themselves is very small: Novopazarska Spa – 180 beds, Rajcinovica Spa – 100 beds and Pribojska Spa – 126 beds [41,42]. In the period 1991–2009 the annual number of tourists decreased from 23,077 to 11,860 in Novi Pazar. In the same period in Priboj, the number of tourists decreased from 10,100 to 3650. In the structure of tourists, the ratio of domestic tourists and foreign tourists remained unchanged. Domestic tourists, in both places, take part in the total turnover of over 90%. Number of nights in 2009 in Novi Pazar was 66,282, which represents an average of 6.7 nights per guest. In Priboj 17,281 nights is recorded and an average of 4.5 nights per tourist.

The main tourist season in spas of the RR is related to the period June–September. Due to the lack of facilities and inconsistency with the market, the dominant healing function is associated with the summer half of the year [17]. Accommodation facilities in Novi Pazar and Priboj are characterised by low occupancy. In order to establish profitability and record an increase in number of tourists, in addition to health programs, there is an offer of various forms of receptive tourism of subsidising character: sports trainings, excursions, seminars, conferences and the like. In the last 10 years several households affirmed for development of rural and cultural tourism in Priboj. This is particularly important when we take into consideration the process of demographic emptying of villages in Priboj region and the economic underdevelopment of Priboj itself (closure or bankruptcy of the largest Priboj industrial buildings, which were a main source of income for both the urban and the rural population).

The use of used and unused TM waters within the spa cycle may have a different, more convenient and economical model. The practice in the spas of Serbia has shown that partial use of energy from thermal waters represents a loss of energy and direct discharge of thermal waters in nature can create environmental problems [10]. According to him, the use of already used thermal waters can serve for different purposes. Table 3 shows some of the possibilities of utilisation of the TM springs of RR based on water temperature.

Table 3
Possible use of thermal waters in spa areas of Raska region.
Source: Associations of Serbian Spas, an spa overview of Republic of Serbia (Available from: http://www.udruzenjebanja.co.rs).

Purpose	TM spring	T (°C)
Balneotherapy	NP, PB, RA	37–45
Pools	NP, PB, RA, CE	22–30
Sanitary hot water	NP, RA	40–50
Space heating	NP	50–65
Wall and floor heating	NP, PB, RA	30–50

Note: NP – Novopazarska Spa, PB – Pribojska Spa, RA – Rajcinovica Spa, and CE – Cedovo springs.

Direct use of the heat energy of TM waters is also one of the possibilities of their utilisation. In six municipalities of RR, in the driving purpose and in heating plants about 6000 t of various fossil fuels are spent annually, most of which are crude oil and coal [43,44]. The total energy of TM sources in the RR of 195.06 TJ/year is equivalent to the energy of 6655.61 t of coal or 4658.92 t of crude oil. Therefore, the use of thermal energy in the economy and households instead of conventional fuels would certainly reduce the cost of labour and life and have positive impact on the environment and spa environment. The principle of substitution of energy sources is particularly desirable in the RR which stands for one of the coldest regions in Serbia on average [45]. The direct use of heat energy of water could be provided by use of heat pumps. Their use would be easier in buildings which already have installations for heat systems (steam heating): sub-stations, pipes, pumps, and radiators. Antonijevic and Komatina [46] suggest a system of heat pumps with two levels which also uses subgeothermal waters and temperatures in the interval 10–30 °C.

TM springs in Novopazarska, Pribojska and Rajcinovica Spas are natural tourist motives and resources that are in the function of tourism development of the local municipalities and RR. Spas maintained over time their basic health resort and rehabilitation function and are important mainly for the local population. During the period of modern tourism, they are not affirmed and positioned among the developed spas in Serbia. Priboj and Novi Pazar, in the last 20 years, in their strategies defined tourism as one of the directions of development. Tourist offer is planned by emphasising the complementarity of spas with the local natural tourist values, the multi-ethnic culture, monumental heritage and sacred architecture of world importance. However, tourism by its multiplicative effects does not encourage trade, services, transport and infrastructure. Also, it has no effect on employment, gross domestic product and income of local people. All these indicate that it still has not been an important factor for economic revitalisation.

6. Conclusion

The study of geothermal energy of TM sources in the RR is important from the aspect of the regional energy balance. Inventory and systematisation of natural resources indicate that they have not been explored and exploited. Geological base of geothermal areas is diverse: from the Mesozoic limestone and diabase–chert formation which condition HCO_3 waters of Pribojska Spa to volcanic and plutonic rocks of Novopazarska hyper-thermal Spa. TM waters at four investigated springs differ by physical and chemical characteristics. Common to all is to be used extensively for the health resort and rehabilitation needs of local people and tourists. Individually, each has its advantages and limitations on use. Individually, the springs of Novopazarska Spa are the most

promising according to water temperature and could have several purposes: balneotherapy, pools, sanitary hot water, space heating, and wall and floor heating. According to therapeutically active components Rajcinovica Spa and Pribojska Spa stand out. In addition to the existing water use, water temperature, total energy of the TM sources in the RR of 195.06 TJ and equivalence of energy point to future possibilities for use in industry and households. We believe that the direct use of the heat energy of water in balneology centres during the colder period of the year would significantly reduce heating costs. The use of renewable energy sources such as TM sources we consider useful for Raska and regions of similar population size with low total consumption of conventional fuels, low industrialisation and urbanisation. Built balneology infrastructure in Novopazarska Spa and Pribojska Spa (swimming pools, bathrooms, medical and rehabilitation and tourist facilities) does not correspond to modern tourism demand and the modernisation is necessary. Also, recovery and rehabilitation, with promotion of a healthy lifestyle have to be more represented in the tourist offer of the RR, generally known for its preserved natural environment.

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